THE HERRINGBONE MILKING SYSTEM

Economic Appraisal, Labor Efficiency Analysis, and Adjustment Possibilities

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PREFACE

New technology is constantly being developed through research and is continually becoming available to farmers. One of the more important new developments which seem to hold promise for greater efficiency in dairy farming is the herringbone milking system. This system combines well with such modern improvements as loose housing of dairy cows, pipeline milking, and bulk handling of feed and milk. The herringbone system can be a vital cog in the progress toward the greater efficiency dairy farming needs if it is to keep pace with progress in most other types of farming.

In this report, new information on the herringbone milking system has been brought together and analyzed. The herringbone is compared with other milking systems for different farm situations, and its possible impact on dairy farming is considered. The results should be of interest to dairy farmers who are considering changes in their milking systems, particularly those who are thinking also of expanding the size of their herds. The results may be of interest to others who wish to keep abreast of current developments in dairy farming and to size up prospective changes.

The author gratefully acknowledges the assistance of all those who helped make this study possible. Special appreciation is expressed to the dairy farmers who permitted their milking operations to be studied in detail and to the many agricultural economists and agricultural engineers, in both the State colleges and the U. S. Department of Agriculture, who helped greatly in the field work and in certain phases of the analysis.

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Economic Appraisal, Labor Efficiency Analysis, and Adjustment Possibilities

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SUMMARY AND CONCLUSIONS

The herringbone milking system is a relatively new milking system that is gaining favor among dairymen. Normally, it is a two-sided, two-level, walk-through parlor, in which the cows are angle-parked at about 30 degrees with the operator's pit. The cows are not individually stalled; they share a common stall area and are held in position by retaining pipe gates at each end of the stall area. Concentrates are fed in the parlor by the use of pull ropes that are connected to the central control panel at the entrance end of the operator's pit.

The superior efficiency of this system is based on two major features--group handling of the cows and placement of the cows in the parlor. Group handling reduces the cow routine time and allows one group of cows to be readied while another group is being milked. The angle-parking feature of this arrangement permits a compact system in which the cows' udders are spaced only 36 to 39 inches apart and are easily accessible to the operator. The spacing between udders in conventional milking parlors is approximately 9 feet.

Herringbone milking systems range in total cost from slightly less than $10,000 to $25,000 or more, depending on the size and completeness of the system. As compared with other systems, however, the compactness of the herringbone reduces the area required per cow and may actually lower the building cost per cow. Substantially more cows can be handled in the herringbone than in conventional milking systems. Although the overall cost of the system may seem high, the current per cow cost based on the number of cows that can be milked and cared for usually ranges from $150 to $190--considerably lower than for any other milking system.

Labor efficiency in the herringbone milking system is generally high. Operator travel is less than that in conventional systems, chiefly because of the reduction in linear travel between cows to about a third of that in any known conventional system. The number of cows milked per man-hour varies with the size of the system but is usually greater in the herringbone than in conventional systems of comparable size. For 2,318 cows timed during the study, the average time--time spent by the operator on each cow while in the herringbone milking parlor--amounted to only 0.93 man-minute per cow. With allowance of time for preparation and cleanup, in 2 hours a skilled operator can milk about 85 cows in a herringbone system as compared with about 60 in a conventional milking parlor or a stanchion barn.

Although the herringbone system has many advantages, it has one minor disadvantage. In all herringbones so far available, the operator cannot see whether or not the grain-feeding mechanism is working properly. A downspout may become clogged and thus prevent part or all of the desired quantity of grain from flowing into the feeder before the cow. Any stoppage, and particularly a partial one, is difficult for the operator to detect. Actually, such a stoppage occurs infrequently, and improved design of the mechanism is tending to eliminate the difficulty.

For maximum efficiency, the herringbone milking parlor, like any other parlor, needs to be combined with other facilities to make a well-balanced farmstead system for han-

dling dairy cows. Usually, these facilities include loose housing, pipeline milking, bulk handling of milk and feed, paved feedlots, and good drainage. This combination of facilities sets the stage for profitable adjustments in size of herd, size of labor force, alternative enterprises, feed production and other phases of the farm business. The herringbone parlor is only one part of the dairy farm business, but many farmers are finding it to be a key element, around which other adjustments can be made profitably.

INTRODUCTION

In the last few years, many important advances have been made in the production technology of feed grains, hay, and silage--the crops that support the dairy enterprise. New and improved machinery, increased use of fertilizer and water, new hybrid seed varieties, and many other developments have contributed to an increase in production of feedstuffs per man and a reduction in man-hours of labor. In many instances, the unit cost of production of these crops has been lowered by these advances. By comparison, the labor costs per unit of production in milking and handling the dairy herd have risen sharply. Comparative output per man-hour and returns to labor have lagged consistently behind those of many other farm enterprises. The most rapid way to overcome this lag is to milk more cows per man, but present milking systems and chore routines limit the number of cows that one man can handle.

The operation and management of commercial dairy farms are complex. On such farms, the daily chores, of which milking constitutes about 60 percent, amount to more than 50 percent of the total number of man-hours required per year. Some gains have been made in dairy chore efficiency. Bulk tanks, pipeline milking systems, bulk feed handling, mechanical feeders, barn cleaners, and other improvements have done much to lessen the labor requirements on many dairy farms. However, the milking routine represents a phase of dairy work that has remained comparatively unchanged for many years.

In the United States, a completely new type of milking system is increasing in both number and importance. This is the "herringbone" milking parlor, so called because the angle in which the cows are parked in the parlor resembles the herringbone weave of cloth. The herringbone originated in New Zealand some years ago. In 1956, two American businessmen who visited New Zealand brought the idea to the United States. The first herringbone milking parlor was constructed in Illinois during the winter of 1956-57 and went into operation in February 1957. Since then, several companies have begun producing herringbone milking parlors. By mid-1959 an estimated 1,500 such parlors were in operation or in process of construction in the United States.

An early report from the first herringbone parlor in operation indicated that one man was able to milk 60 cows in slightly less than an hour, or about one cow per minute. This report stimulated farmer interest, as the average milker in a stanchion barn handles only 20 to 30 cows per hour. In 1957, it was reported that a New Zealand dairyman was milking from 80 to 90 cows per hour. In early 1958, still another report from New Zealand stated that one operator using 11 units had milked 110 cows in an hour with the herringbone system.

Following these reports, herringbone systems began to dot the American countryside as farmers experimented with the new parlor. Because little information was available on the herringbone, many types, designs, and sizes were built by the first farmers who used the system. The first size to gain popularity, chiefly because of dealer promotion, was the double-6, which consists of two rows of six stalls arranged in herringbone fashion on each side of the operator pit. The double-6 parlor has six milking units. Another early arrangement, the single-6, had a single row of six stalls arranged in herringbone fashion on one side of the operator pit. In this system, the operator uses only three milking units--he milks the first, third, and fifth cows on the first cycle, then transfers the units to the second, fourth, and sixth cows on the second cycle. A variation of the single-6 herringbone has six rather than three milking units. Other herringbone systems in use are the double-3, double-4, double-5, double-8, and double-10. They are the same style as the double-6 system described, except for the number of milking stalls. The double-8 and larger herringbones are operated by two men.

The reports of phenomenal milking speeds obtained through use of the herringbone milking systems caused some well-founded concern among dairy specialists, who were aware that in many instances the milking speeds were attained at the expense of good milking habits and practices. However, they realized also that, if handled properly, the herringbone could reduce labor and costs. To them, one of the chief problems was the size of herringbone parlor to build.

The typical herringbone milking system is a two-sided, two-level, walk-through parlor, in which the cows are handled in groups or batches. The cows are let in, fed, prepared, milked, and let out in groups, not as individuals. Each milking unit serves two cows in horizontally-opposed stalls. The milking units are attached directly to the vacuum line and the pipeline that run the full length of the operator pit just over the head of the operator. The angle parking arrangement allows 36 to 39 inches of linear space per cow, which means that the udder of the first cow is only 15 feet from the udder of the sixth cow in the line. This may be compared with approximately 16 to 18 feet between the udders of the first and third cow in a tandem arrangement. The herringbone reduces the operator's linear travel per cow by as much as 50 percent.

In brief, the herringbone system operates as follows. A group of cows is let in on one side of the parlor, where they are fed, washed and forestripped, and the milking units are attached. While these cows are being milked, another group is let in on the opposite side of the parlor; these cows are fed, washed, and readied for the milking units. As the milking of each cow in the first group is finished, the machine is removed. With a single step, the operator carries it across the pit to the cow immediately opposite and attaches it. When the last machine in use on the first group has been removed and transferred, these cows are let out and another group is let in. This constitutes a half-cycle in the parlor.

OBJECTIVES OF THE STUDY

This study resulted from the nationwide interest shown in the first herringbone milking parlors. The herringbone system of milking has important farm-management aspects. In most instances, it reduces labor requirements and offers adjustment possibilities for the dairy farmer. But it is new in this country, and little research on its farm-management aspects has been undertaken. The objectives of the study were:

(1) To determine and describe the present use of the herringbone system in selected areas of the United States;
(2) To determine the capital and labor requirements for this system as compared with other systems;
(3) To analyze the economic impact of this system on dairy farms of different sizes and intensities of operation;
(4) To analyze the adjustments that may be made to fit the system into the management plan on typical commercial dairy farms.

METHOD OF STUDY

Herringbone milking systems on 51 farms in 18 States were studied in detail in the fall of 1958. As nearly as possible, the farms were chosen to represent the various sizes, designs, and types of herringbone systems in operation.

Data were collected for each farm on size, investment, number of cows, previous milking system, labor supply, and changes made or contemplated because of the herringbone system. In addition, a detailed time-study analysis was made of each milking operation to ascertain work rates, labor requirements, labor efficiency, and so on, for each herringbone system.

Farms were selected in various dairy areas to determine whether location and climate affect the operation of a herringbone milking system. Areas studied were the Midwest, Northeast, and Southeast.

CHARACTERISTICS OF FARMS HAVING HERRINGBONE MILKING SYSTEMS

The farms studied on which herringbone milking systems have been installed are considerably larger than the average commercial dairy farm. The 51 farms studied averaged 328 acres. Cropland per farm averaged 253 acres and pastureland 61

acres. Of the farm operators, 43 were owners and 8 were share tenants. A very close working relationship appeared to exist between tenant and owner on the eight farms operated by share tenants.

THE DAIRY ENTERPRISE

On 46 of the farms studied, dairying contributed more than 90 percent of the total farm receipts. Each of the 51 farmers sold fluid milk to markets usually within a 40-mile radius. Herd size ranged from 17 to 221 cows; the milking herd averaged 61 cows. A year earlier the number of cows milked on these farms averaged 46, and 2 years earlier the average was 38. In 1958, the farms averaged 39 heifers; no doubt this was a motivating factor in the installation of a new milking system.

The average labor force per farm was 2.4 men. The larger farms had 3 to 7 full-time employees, while the smaller farms were one-man units, with some hired help during summer labor peaks. Most of the farmers interviewed visualized a considerable increase in their herds with little or no increase in the labor forces.

PREVIOUS MILKING SYSTEMS

Before herringbone milking parlors were installed, 39 of the 51 farm operators in this survey used stanchion barns for housing and milking. The stanchion barns had an average of 32 stalls, with each operator handling 45 cows per milking. As the number of cows milked exceeded the number of stalls, part of the herd had to be moved out of the stanchion barn during each milking. This slowed the operator and caused labor inefficiencies. The 45-cow herd was milked in approximately 93 minutes by an average labor force of 1.8 men, who used 3.1 milking machines and milked at a rate of about 16 cows per man-hour. Each operator handled 1.7 machines.

The operators on 12 farms had previously used loose housing in connection with some type of milking parlor. Parlors used included floor-level and elevated arrangements. Some were walk-in, back-out types, but most of the parlors were walk-through models with either tandem or side-opening stalls. Three of the parlors were equipped with pipeline systems. An average of 51 cows were milked in approximately 89 minutes by a labor force of 1.3 men, who operated 2.8 machines. In this arrangement, each milker handled 2.2 machines and milked approximately 26.4 cows per man-hour.

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Three of the herringbone milking systems studied had stalls on only one side of the parlor. These systems are commonly referred to as "single" herringbones. Two of them were single-6's, one with three milking units and the other with six. The third was a single-8 with four milking units. These stop-gap systems were for use until the farmer could afford to install the other side to make the single systems into double herringbones.

The other 48 herringbones were two-sided parlors, or "double" herringbones. They ranged in size from a double-3 to a double-8. Two double-10's under construction were observed, but no data concerning them were collected. The double herringbones included 24 double-6's, 12 double-4's, 6 double-8's, 5 double-5's, and 1 double-3.

Dimensions

The dimensions of the herringbone systems studied varied considerably because of lack of standardization among the early experimental models, differences among manufacturers, personal preferences of builders, and the like. Manufacturers have done much to standardize the systems in later production models and, except for minor differences, they are similar. The only major difference between a double-3 and a double-8 herringbone parlor is the increase in length made necessary by the addition of five milking stalls on each side of the parlor. For each stall added, the linear pit area is increased 36 to 39 inches, according to the manufacturer's specifications. The double herringbones vary slightly in width because

of manufacturers' differences and, in some instances, because of milk-code regulations.

The only double-3 herringbone parlor studied was planned originally as a conventional milking parlor with two side-opening stalls on each side of a 5-foot-wide operator pit. Just before installation, the farmer changed to a double-3 herringbone, which fitted into the building with space to spare. The dimensions of this unit are not pertinent to the study; the unit was adapted from a different floor plan.

Figures 1 through 4 present floor plans for a double-4 through a double-8 herringbone milking system. These parlors are standardized as much as possible; they vary in length in proportion to the number of stalls. All operator pits are 48 inches from curb to curb. This allows plenty of elbowroom for the operator and accommodates a milk tester at the same time. Four-foot service alleys flank each end of the operator pit to allow for free operator movement within the parlor. The stall areas on each side of the operator's pit are about 6 feet wide. The inside width of a double herringbone can be computed by adding the width of the two stall areas to the width of the pit--in the figures shown, this amounts to 16 feet. The length of the building can be found by adding the width of the two end service alleys to the linear stall dimensions of each set of stalls. In the double-4 pictured, the inside building length is 21 feet, which allows 39 inches of linear pit space per cow.

Figure 5 compares the building space needed for two conventional milking parlors of different sizes and for a double-4 herringbone. The difference in building space required for the double-4 herringbone and the two-sided, 3-stall, tandem walk-through milking parlor, is less than 10 square feet. It is generally agreed that the double-3 stall, tandem walk-through parlor is one of the most efficient 1-man milking systems among conventional parlors. In a later section, the two systems are compared as to operating efficiency.

Construction Features

The basic building material used for construction of the herringbone system was the 8- by 8- by 16-inch concrete block. Twenty-nine of the herringbones were constructed of this material. The glazed tile blocks used both inside and outside their herringbones by 14 farmers added considerably to the outward appearance of the structures and made cleaning easier. Six farmers bought flat-roofed, prefabricated structures that had the disadvantage of not having built-in feed-storage areas. Two of the herringbones had wooden frames; the exterior walls were covered with sheet metal and the inside walls with commercial building board tempered to resist moisture.

Of the 51 herringbones, 33 were separate and distinct structures; whereas 18 were constructed against, or partly or wholly within, existing structures.

Cost of Buildings and Equipment

Building costs per square foot for the herringbones studied ranged from $2.12 to $6.86. All were built in 1957 and 1958. Several of the smaller herringbones were built inside existing structures, and only two walls, the ceiling, and the floor were needed. This kept construction costs down. Concrete block structures built apart from existing structures averaged $3.78 per square foot. The buildings made entirely of glazed tile block were most expensive. They averaged about $6.41 per square foot, but the owners of these units liked the ease of cleaning and upkeep.

A type of building that seems to have gained favor among recent builders features concrete block construction to keep down costs, with the interior faced with glazed tile. The glazed tile interiors add from $0.70 to $0.90 to the cost per square foot but do away with painting and most of the upkeep and make cleaning easier. Floors and pit areas are of poured concrete. The roof may be either metal, composition shingles or built-up roofing; it is arched or domed to allow for overhead feed storage above the milking area. The costs shown in table 1 are based on this type of structure with the work to be done on contract. Use of farm labor in construction would reduce costs somewhat. The equipment of each system is balanced according to the size of the system and the number of cows milked.

The two conventional milking parlors that are compared with the herringbones in table 1 were chosen because they represent the maximum size that can be handled by one operator. The side-opening 4-stall U parlor might have been included in this group, but it differs from the double-2 side-opening type in one major respect--in the former, the cows walk a much greater distance in

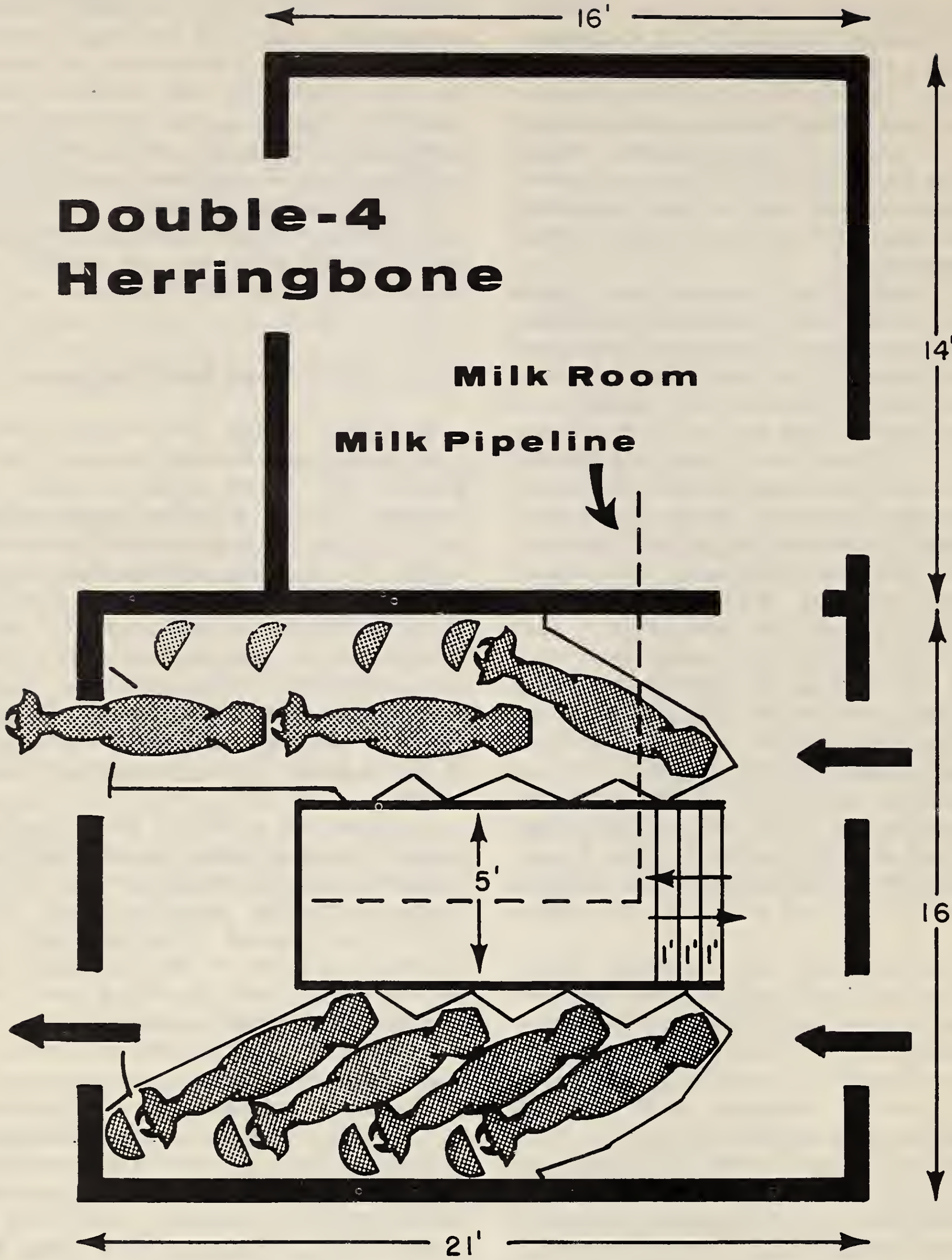

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Figure 1

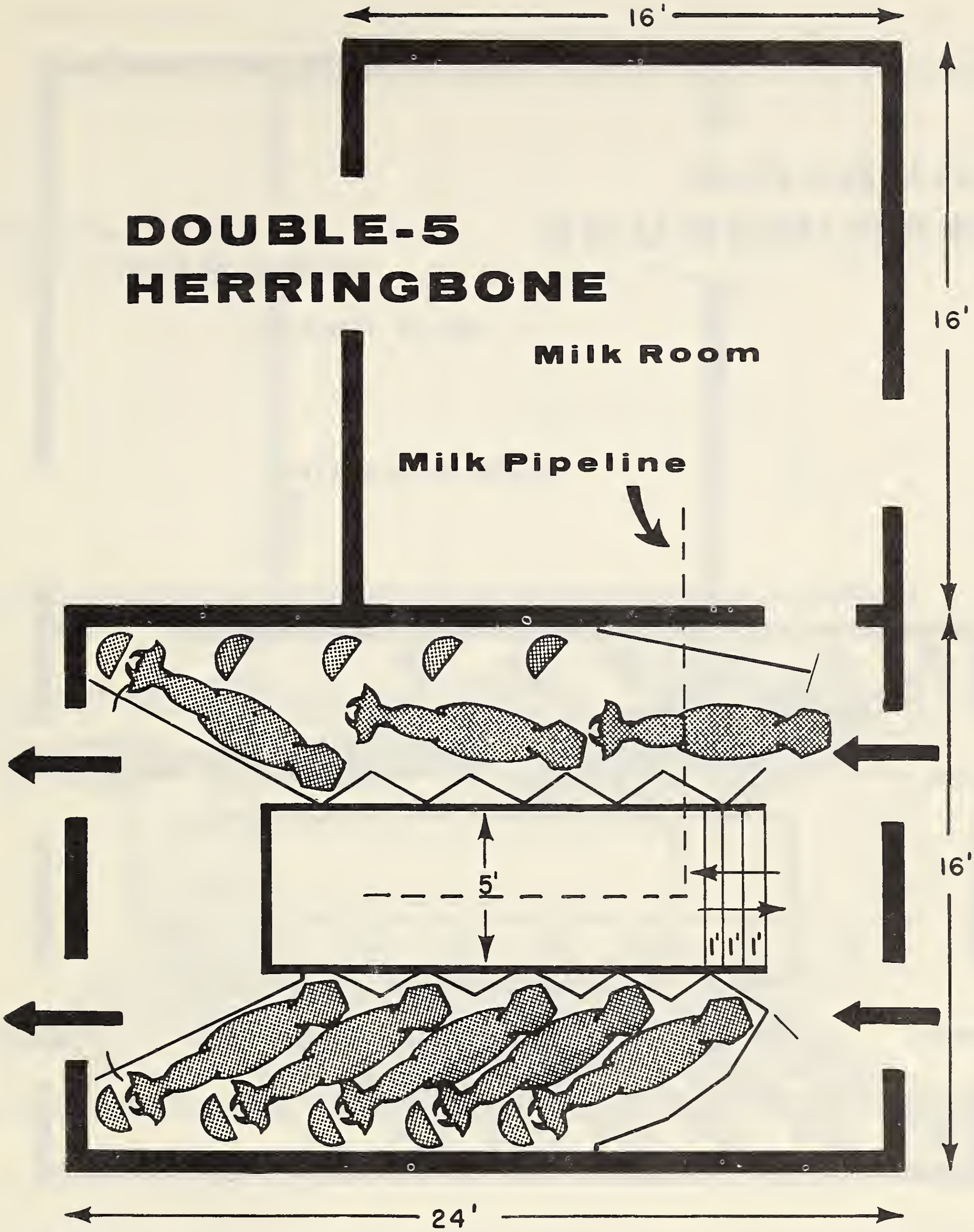

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Figure 2

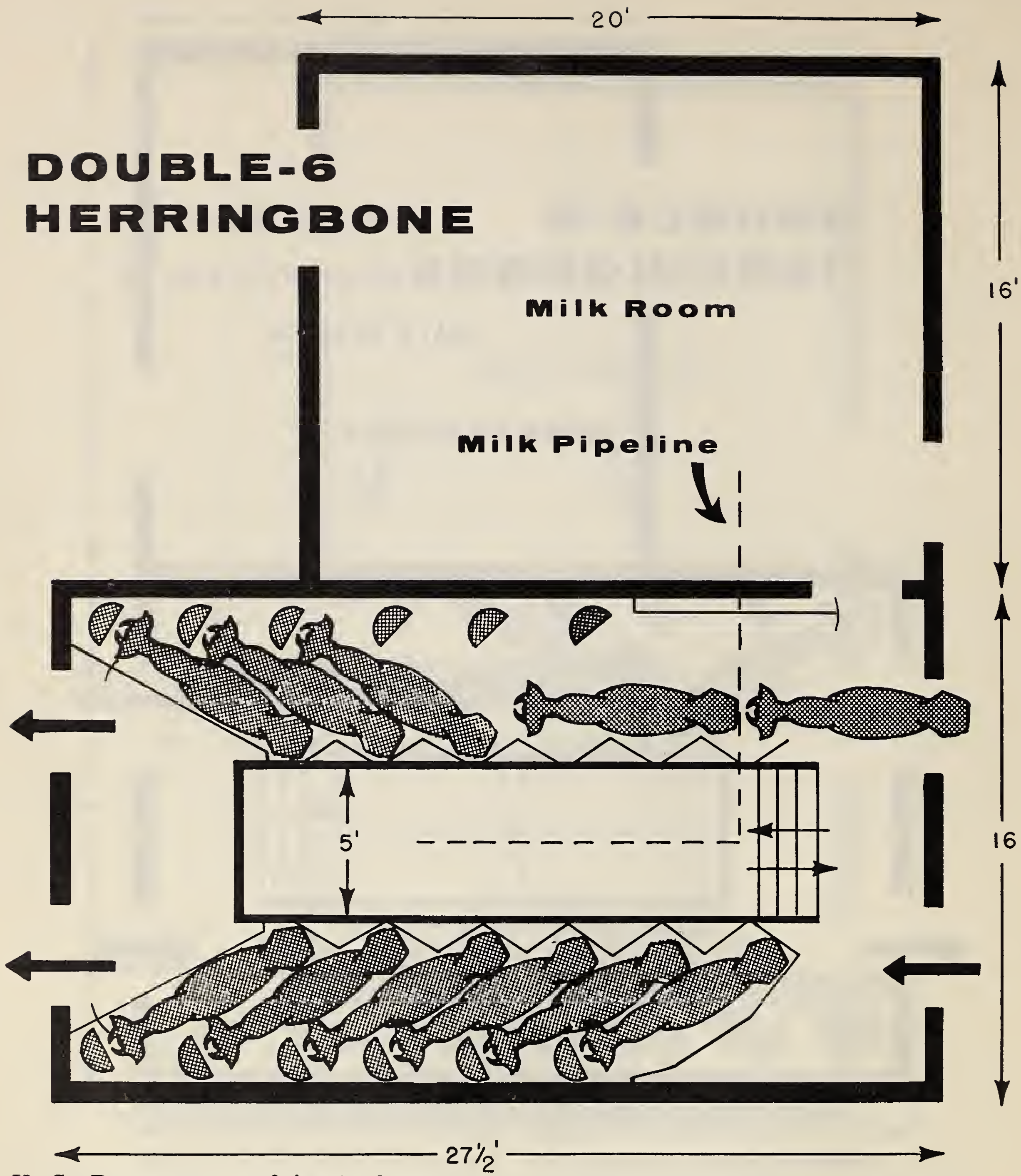

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Figure 3

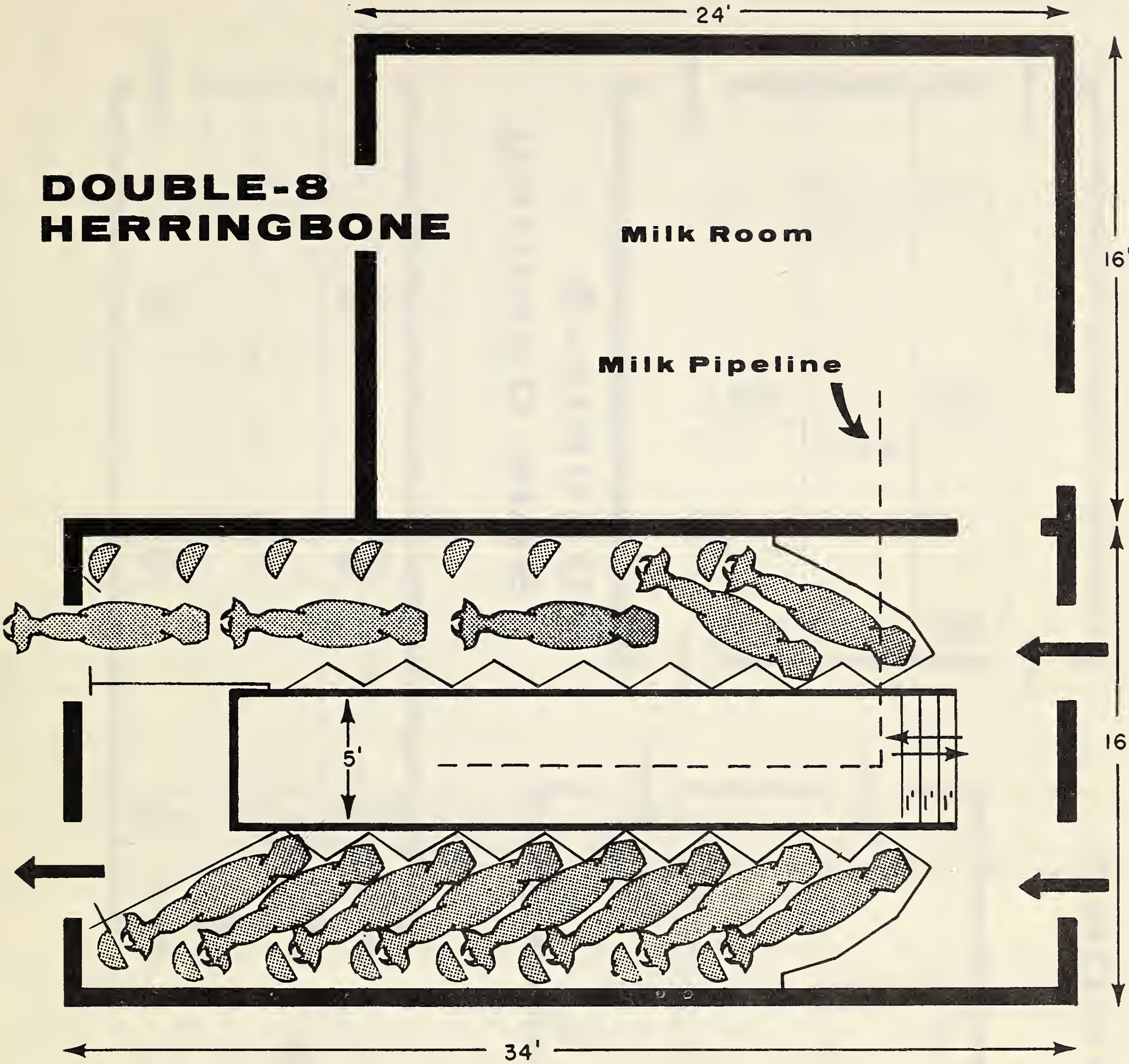

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Figure 4

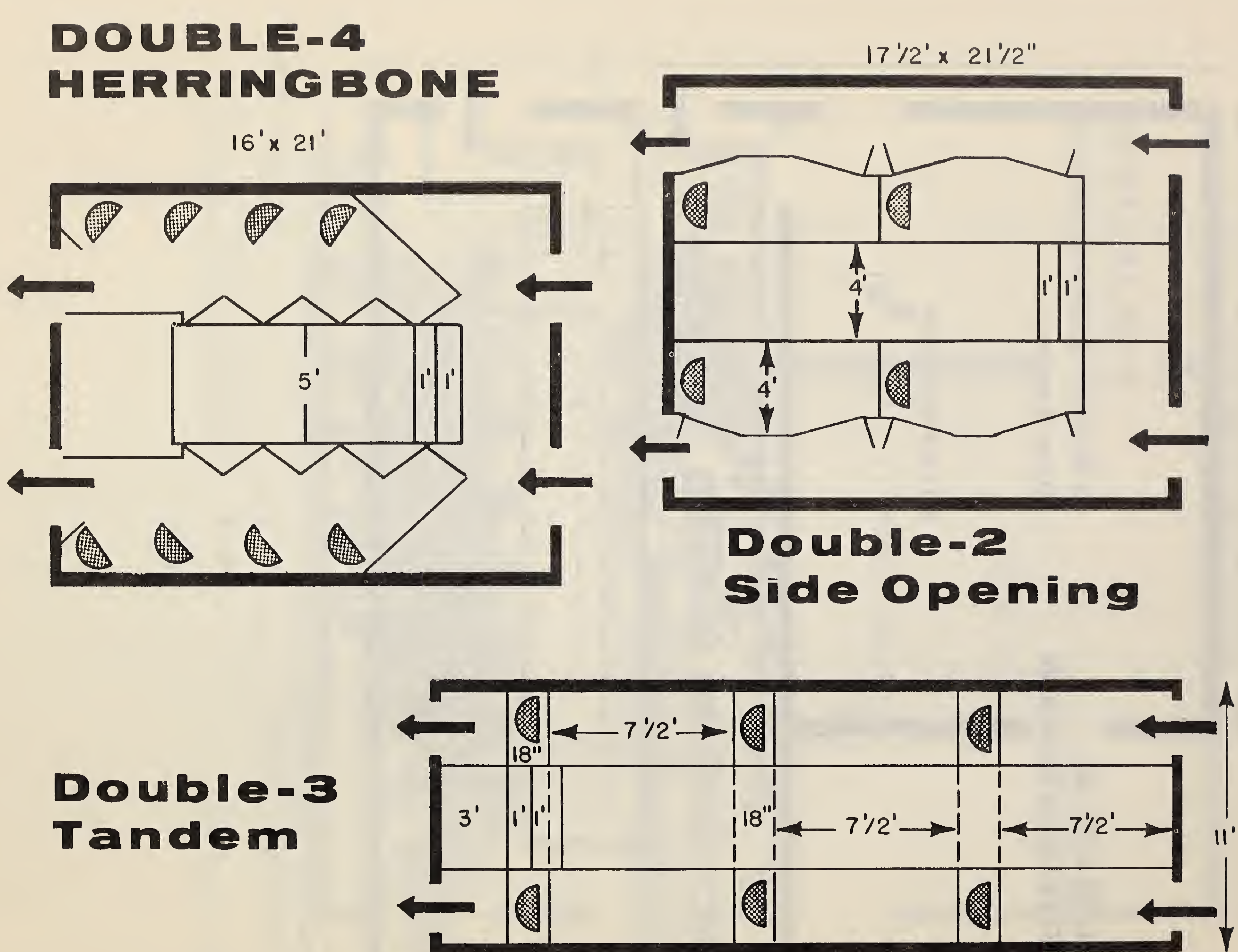

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Figure 5

Table 1.--Features and investment costs of one-man milking parlors: Conventional parlors compared with herringbone parlors of different sizes

Item	Unit	Double-3 tandem walk-through	Double-2 side opening	Double-4 herring-bone	Double-5 herring-bone	Double-6 herring-bone
Parlor dimensions, inside----	Foot	10.5x31	17.5x21.5	16x21	16x24	16x27.5
Milk room dimensions, inside[1]	do.	14x16	14x16	14x16	16x16	16x20
Building size----------------	Sq. ft.	550	600	560	640	760
Stalls-----------------------	Number	6	4	8	10	12
Milking units----------------	do.	3	4	4	5	6
Bulk tank capacity-----------	Gallon	500	500	600	750	900
Cow capacity[2]--------------	Number	64	56	86	105	128
Investment costs, 1958 prices:						
Building costs-------------	Dollar	2,310	2,520	2,352	2,688	3,192
Per square foot----------	do.	4.20	4.20	4.20	4.20	4.20
Per stall----------------	do.	385	630	294	269	266
Per cow milked-----------	do.	36	45	27	25	25
Equipment costs[3]-----------	do.	5,350	5,150	5,900	6,873	8,200
Per stall----------------	do.	892	1,288	738	687	683
Per cow milked-----------	do.	84	92	69	65	64
Total costs----------------	do.	7,660	7,670	8,252	9,561	11,392
Per stall----------------	do.	1,277	1,918	1,032	956	949
Per cow milked-----------	do.	120	137	96	91	89

[1] Milk room size allows 50 percent of the floor area to be free and uncluttered after all equipment is in place.

[2] Average number of cows milked over a 2-hour period, based on 5.5 minutes of milking time per cow for cows producing 8,500 pounds of milk annually.

[3] Equipment includes stalls, gravity-type feeders, pipeline system, milking units, semiautomatic wash system, overhead grain storage, bulk tank, hot water heater, lighting fixtures, door fixtures, plumbing, and electrical wiring.

entering and leaving the parlor than they do in the latter.

Differences in the costs of the milking systems are due to variations in building size, number of stalls and milking units, and length of the pipeline. All units have pipelines, bulk tanks, semiautomatic wash systems, glazed tile interiors, and gravity-type feeders that are served from overhead grain-storage bins.

LABOR EFFICIENCY IN THE HERRINGBONE MILKING SYSTEM

The gains in labor efficiency realized in the herringbone milking system are due to two basic ideas or principles--group or "batch" handling of cows and placement of the cows within the parlor. A cow milked in the herringbone parlor tends to lose her identity as an individual and become just another member of a living machine for production of milk. The cows enter and leave the herringbone as a group--the entrance and exit doors are opened and closed once for a group that may number from four to eight cows, according to the size of the system. The time required for four cows to enter a herringbone parlor differs only slightly from the time required for one cow to enter. Once the leader in a group is committed, the others tend to follow; and, as each following cow has a shorter distance to travel to her stall, she is almost in position by the time the cow ahead of her is positioned. The average time for the individual

cow to enter and leave the herringbone becomes very short when the group times are divided by the number of cows.

Feed is metered to cows by means of a control panel located on each side of the operator pit at the entrance end of the parlor. While the operator works the controls for the entrance door with one hand, he works the controls for the feed panel with the other. Normally, by the time the last cow in line is in position and the entrance door is closed, the grain ration has been released to the feedboxes. This overlapping of these two work elements saves considerable time and travel as compared with conventional milking systems. The feeders and feedboxes are located against the outside walls and are connected to the feed-control panel by pull ropes. The pull rope activates a rachet-type feeder control that permits the operator to meter feed into the feedbox according to the requirements of each cow.

The cows are usually washed, dried, and foremilked in sequence. For washing purposes, hoses, usually 5 to 7 feet long, are located in such a way that each serves two stalls. The hoses are equipped with spray nozzles similar to the nozzle used in rinsing dishes. With this arrangement, a double-6 herringbone requires three such hoses on each side of the operator pit.

The placement of cows in the herringbone system also contributes to its efficiency. The cows are parked in the stall area at a 25° to 30° angle to the operator pit. As cows face the outer wall, the operator has easy access to each cow's udder. There is no separation between individual cows, which allows a group of cows to be parked in a close, compact arrangement. The linear distance between udders is from 36 to 39 inches in the herringbone, as compared with about 9 feet in conventional milking parlors. Building and pipeline costs are less because the floor space per cow is reduced and the operator pit is shortened on a per stall basis.

FACTORS THAT AFFECT MILKING TIME

Dairy specialists have pointed out that operators who try to handle too many milking machines sacrifice good milking procedures. The concern here is mainly with the length of time the milking machine remains on the cow--the "machine-on" time. Continued use of the milking unit after milking has been completed, which is referred to as "overmilking," may damage the udder and increase the possibility of mastitis infection.

Cow Milking-Out Time

Opinion differs concerning the average time necessary for a cow to milk out. Little information exists on the subject of milk-out times for cows according to the amount of milk they produce. While milk-out and machine-on times are normally considered the same, this may not be true in a strictly technical sense. After a cow has milked out, the milking machine may be allowed to remain on the cow, even though no milk is obtained. In this case, the machine-on time is composed of milk-out time plus some time when the machine is idle, even though it may be pulsating on the milked-out cow. However, in the study reported, the milk-out time and the machine-on time were considered to be of equal duration.

Sturrock and Brayshaw [1] state that the milk-out time of a given cow is governed by the amount of milk produced, the size of the teat canal, and the design of the milking machine. They state also that a cow producing 10 pounds of milk per milking should milk out in about 3-1/2 minutes; that 15 pounds would require about 4-1/2 minutes; and that 20 pounds would require about 5 minutes. During their study, however, the authors timed 1,661 cows and found that milking machines were left on the cow for an average of 7.46 minutes. In their own words, "this is certainly too long and indicates a substantial amount of overmilking. One cannot altogether blame the cowmen. It is not easy to judge when a cow has stopped milking and the cowman may continue to massage the udder long after any but trifling amounts of milk are being withdrawn."

A substantial number of timings were made at the University of Minnesota to determine milk-out times for cows milked in stanchion barns.[2] The average milk-out time for these cows was 4.68 minutes. A

[1] Sturrock, F. G., and Brayshaw, G. H. Planning the Farm To Save Labor. Cambridge Univ., School Agr., Farm Econ. Rpt. 47, 45 pp., 1958.

[2] Unpublished data from R. E. Larson, Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture [1958].

Purdue study[3] indicated that the average milk-out time for 13 herds milked in herringbone parlors was 5.08 minutes per cow.

In the course of this study, the milk-out times for 2,318 cows milked in 51 herringbone systems were obtained by stopwatch. The milk-out time for this group of cows averaged 6.02 minutes and ranged from 2.48 to 14.98 minutes. The average production per cow during these timed milking procedures ranged from 13.6 to 26.1 pounds per milking. Herd averages ranged from 8,200 to 16,129 pounds per cow per year. In all instances, these averages were higher than the individual State averages.

One of the earliest controversies that involved the herringbone milking system centered around the number of milking units one operator could handle properly. Most manufacturers and dealers chose to promote the double-6 herringbone as the ideal size of system for one-man operation. Many persons felt that this system was too large for one operator and would mean that the milking units would remain on the cows too long.

Contrary to popular belief, the 1,429 cows milked in the double-6 herringbones had the shortest milk-out times; they averaged 5.87 minutes per cow. These cows also averaged 0.6 of a pound more milk per milking than the average cow in the study reported. The double-4 herringbones allowed the operators to milk at a more leisurely pace with some idle time, yet the cows milked in this system required an average of 6.28 minutes to milk out and produced 16.6 pounds of milk per animal. This indicates only that milk-out times are not the sole criterion to be used in evaluating the efficiency of the herringbone system; it does not mean that the double-6 herringbone system is superior to the double-4 in actual milking procedure.

The clear plastic milklines now used on most milking units may contribute inadvertently to an increase in milk-out times. Most operators tend to gage visually the flow of milk through these lines as an aid in determining when cows are milked out. The smaller flow of milk obtained during machine stripping may be activated by the surge of vacuum in such a way that the operator may find it difficult to distinguish between milk and froth in the milkline. In many instances, the operator may continue to milk a cow when little or no milk is moving through the line. Operators should rely on the feel and condition of the cows' udders to determine when milking is completed, as they did when milklines were made of rubber.

[3]Morris, W. H. M., and Vestergaard, E. C. What To Expect From The Herringbone Milking System, Purdue Agr. Expt. Sta. Jour. Paper 1370 [1958].

Machine-Cycle Time

Machine-cycle time is defined as the interval between the time the machine is attached to the first cow and the time it is removed and placed on the second cow. Machine-cycle time, therefore, is made up of machine-on time and idle-machine time. Machine-cycle time can be shortened in several ways. Any method used to shorten the milk-out time of the cows in a herd decreases the machine-cycle time. Brief but careful machine stripping and prompt removal of the milking unit when milking is completed shorten the machine-cycle time in many instances in which milk-out times exceed 6 minutes. In the last few years, fast milking has been emphasized, and breeders are beginning to include this item in their breed-selection data. If high-producing cows can be bred to milk out in perhaps 4 minutes, a major improvement in milking times will be made.

Idle-machine time depends mainly upon the design of the milking system. Regardless of where the milking is performed, the machine must remain idle from the time it is removed from one cow until it is attached to another. In a stanchion barn after the farmer has milked two cows, he must uncouple the milking unit and move it to a new location before he can attach it again. The time required to uncouple and hook up the milking unit, plus the travel time involved, keep idle-machine time high in the stanchion barn.

In conventional milking parlors, idle-machine time depends chiefly on the layout of the system. If the parlor has a milking unit for each stall, the idle-machine time is proportionately high. After the farmer has removed the milking unit, he must let out the milked-out cow and let in, feed, wash, foremilk, and attach the machine on a fresh cow before idle-machine time ceases. Most single- and two-sided parlors equipped with side-opening stalls fall into this group.

Two-sided tandem walk-through parlors and the double herringbone milking systems usually have one machine to serve two cows. This doubles the number of stalls required per milking unit but permits the operator to let in, feed, and prepare a cow

while the machine is operating on the other side of the pit. With a pit width of about 48 inches, the operator can remove the milking unit, turn, move about 1-1/2 steps, and be in position to attach the unit on the next cow in a very short time. The time required for this function will range from 0.09 to 0.17 minute, depending on the speed of the operator, the width of the pit, and the cow being milked. When this short period is compared with machine-on time on a percentage basis, the idle time is low. A system of this kind shortens materially the machine-cycle time.

COW ROUTINE TIME

Cow routine time is the time required by the operator to perform all work operations connected with a cow during the milking cycle. The cow routine time usually occurs while the machine cycle is also in progress. These functions of cow routine vary with the operator's milking habits, design of the milking system, weather or seasonal conditions, the feeding system, and the particular cow involved. When the study on which this report is based started in the early fall, many operations were almost standard in their application; but, as the winter advanced, some operations were changed and others added. The operations or job elements described here have been standardized to some extent in order to make comparisons between farms easier. The times required to perform these job elements may be divided into two groups: (1) The times over which the operator has little control and (2) the times that are controlled by the operator. Descriptions of the basic jobs or work elements for the herringbone milking system follow.

The times largely beyond the control of the operator are as follows:

Let cows in.--Time required to let cows in begins when the operator reaches for the handle that opens the holding gate at the end of the stall area and continues with the subsequent action of opening the sliding door that allows the cows to file into the parlor. The operator holds the door open with one hand and feeds the cows with the other by operating pull ropes attached to a control panel located on each side of the operator's pit at the entrance end of the parlor. When the last cow of the group has entered the parlor, the operator closes the outside door and the retaining gate.

Feed cows.--Feeding cows is a separate job element in conventional milking parlors; but, in the herringbone system, feeding is part of the let-in operation. No charge is made for feeding time.

Let cows out.--When all the cows in a group have completed milking, the group is let out of the parlor. This operation starts when the operator begins moving into position at the exit end of the herringbone. From this position, he opens the outside sliding door and then opens the retaining gate at the end of the stall area. When the cows have cleared the parlor, the gate and door are closed and the let-out operation is finished.

Travel.--Travel time is time spent by the operator in moving from one job station to another. Although in the study travel times were obtained separately, they were later added to the operation being performed at the time, because most of the moves made by the operator included the performance of an operation. In these instances, precedence was given to the operation time instead of the travel time. Travel time required in moving the length of the operator pit ranged from 0.05 minute in the double-4 to 0.09 minute in the double-8 herringbones. When this travel time is divided by the number of cows, it becomes just a fraction over 0.01 minute per cow. This is too small for consideration in a report of this kind, but it may be important to agricultural engineers who work with building designs and functions.

Times controlled by the operator are as follows:

Prepare cow.--The time required to prepare cows varied more than any of the other times. Most variations were the result of adverse weather, health department regulations, and individual work habits. During the summer and early fall, the cows came into the parlor directly from pasture and were clean. The washing operation consisted of quick spraying from the wash hose, drying the udder, and forestripping each quarter into a strip cup. As the season advanced, the cows often came into the parlor with mud caked on their udders, and considerable time was spent cleaning them. Average preparation time ranged from 0.14 to 0.73 man-minute per cow for this opera-

tion. Dairy specialists recommend, and codes may require, that udders be washed thoroughly with water to which a disinfectant has been added and that each be carefully dried, preferably with a disposable paper towel. Use of the strip cup is advocated also.

Attach machine or move and attach machine.--When the first group of cows enters the herringbone system, the milking machines are hanging on hooks beside the stalls. The "attach" operation consists of removing the milking unit from the hook and applying it to the udder. From this point on at each milking cycle, the attach operation differs in that the operation starts with the removal of the unit from a cow on one side of the pit, continues with the transfer of the unit to the opposite side of the pit, and ends with its application to another cow. This job element is often called "move and attach."

Check or aid machine.--In many instances, operators stood in one location and checked visually the milking progress of each cow. As soon as a cow had about completed milking, the operator moved to her side and began machine stripping. Other operators walked along the line of cows and felt each udder in turn to determine milking progress; they used this check as an aid in determining when each cow was milked out. Wherever it was performed, this operation was timed and included in the cow routine time.

Machine strip and remove unit.--Some time-study engineers believe that these two job elements should not be grouped. However, it is almost impossible to determine where one stops and the other begins. While they are machine stripping, many operators often drop one or two teat cups from the udder, usually from the front quarters. This is actually half of the removal operation, but the operator may continue to strip the rear quarters for some time before he removes the other two teat cups. The actual removal operation is fast--the operator grasps the cluster of the milking machine and pulls down gently but firmly in one continuous movement. Actual timings revealed that this required 0.02 to 0.05 minute per cow. Because it is difficult to distinguish between the two job elements, they were grouped for this study.

DESIGN OF THE SYSTEM

The features of the design of the herringbone milking system that contribute to efficiency are:

(1) Angle parking--cows are angled about 30° with the pit area in order to crowd more cows into shorter linear space;
(2) Group handling--cows are handled in batches and not as individual cows;
(3) Two-sided system--cows on one side are readied for milking while cows on the opposite side are being milked;
(4) Feed-control panel--conveniently located feed panel allows operator to feed while standing at entrance of the system;
(5) Entrance and exit controls--entrance and exit doors can be operated manually from the pit area;
(6) Straight-line cow travel--normally each half of the parlor has an entrance and an exit door, which allow cows to walk straight through the parlor. Cows enter and exit from the herringbone faster with this system;
(7) Small operator pit--operator's pit is short and only about 4 feet wide, which reduces travel per cow;
(8) In-place pipeline cleaning--the pipeline system can be washed mechanically in place while operator is performing other chores in the immediate vicinity.

TIMING ANALYSIS

This report is concerned primarily with the economic aspects of the system, and the time-study analysis has been simplified as much as possible without losing any overall accuracy. The basic work or job elements, described previously, were chosen because they represented natural work sequences with clear-cut beginning and ending points necessary for accurate motion timing. As the milking operation is repetitive in its work sequence, it lends itself well to motion-time study.

A few of the farms were timed by the "continuous watch" method, but most were

timed by the "multiple watch, snap-back" method. This method was considered best because some of the work elements were short and occurred within the framework of elements already under observation. The time-study board had three watches to which a fourth was attached to record total elapsed time, which afforded a good system for checking out the time data. If individual times obtained by the snap-back watches did not add to the total elapsed time obtained from the fourth watch, the timings were in error at some point in the analysis. By cross subtraction of element timings within the framework of the analysis, such errors could be found quickly.

Preparation Times

Preparation times included the time required to assemble the equipment, hook up the system in the milk room and in the milking parlor, prepare the rinse water, rinse the system, and start the vacuum pump. Table 2 shows the times required to perform these tasks by size of the herringbones studied and the total time required for preparation of the system for milking.

Some preparation steps were not affected by herringbone size. Apparently the difference in the time required for their performance is due more to the individuals who operate the system and to small differences in system design. The other tasks of preparation were related directly to system size, and the times required to perform these functions became longer as the size increased. The overall shortness of preparation times for the herringbone is due to in-place pipeline cleaning and the fact that the cleanup phase of the previous milking operation leaves the system clean and ready for the next milking.

Milking Times

Milking times included all tasks necessary in the proper performance of the milking chore. Table 3 presents the averages for all the stopwatch times obtained during the milking operation in the herringbones studied. All tasks connected with the cows are grouped under the heading cow routine time, while measures of system efficiency are shown at the bottom of the table. The cow routine time appears to favor the double-6 herringbone system, which has a total of only 0.83 man-minute per cow. This means that a group of 6 cows could be handled by the operator in 4.98 minutes; and, if the machine-cycle time were reduced to 5 minutes per cow, the double-6 herringbone could handle 72 cows per man-hour at the optimum performance level.

There are several possible reasons for the lower cow routine times observed in the double-6 herringbone. First, most of the double-6 herringbones were studied in early fall, when the weather was good and the cows were still on pasture. This made for clean cows and reduced the time spent in cleaning the udders. Second, operators of double-6 herringbones were called upon to operate 6 milking units, and small emergencies often caused the operator to fall slightly behind in his cow routine sequences. To combat this delay, the operator either worked at a greatly accelerated pace for a few minutes or was forced to slight or omit certain work sequences in order to regain his normal work pace. Furthermore, operators of these systems were primarily young, progressive dairymen with good management techniques, who evidently realized that they were working on a very tight schedule and that little time tolerance could be permitted without seriously hampering the work routine. This awareness of a close-tolerance operating schedule keeps the operator alert and on the lookout for conflicts in work routine, the effects of which may be minimized by early observance.

The double-6 is superior also to herringbones of other sizes in overall efficiency. The double-6 systems had the largest number of cows milked per man-hour and the smallest number of man-minutes used per pound of milk obtained. They tied with the double-5 for fewest machine-minutes per pound of milk. If the effects of the fast milking pace and the narrow time tolerances of the double-6 can be moderated without loss of overall efficiency by shorter work routines, faster milking cows, and more skilled operators, this system could well become the most efficient one-man milking system known. Until these drawbacks are eliminated, however, the smaller herringbone may permit a superior job of milking at lower investment and with less physical strain on the operator, as it allows him to milk at a more moderate pace.

Table 2. --Analysis of preparation times for 47 herringbone milking parlors, 1958

Item	Double-4	Double-5	Double-6	Double-8
	Number	*Number*	*Number*	*Number*
Total farms	12	5	24	6
Total cows timed	376	293	1,429	220
Preparation time per milking:	*Minutes*	*Minutes*	*Minutes*	*Minutes*
Fix rinse solution	0.41	0.56	0.43	0.49
Rinse system	.83	.96	.78	1.11
Install in-line filters[1]	1.41	1.73	2.06	2.46
Carry units to parlor	.68	1.03	.96	1.42
Hook up units in parlor	1.27	1.24	1.66	1.95
Connect releaser to bulk tank	.38	.29	.34	.41
Start vacuum pump	.23	.37	.26	.22
Total	5.21	6.18	6.49	8.06

[1] Not all systems had individual filters for each milking unit, but those that did not had 1 main filter usually located just in front of the milk pump.

Table 3. --Analysis of milking times for 47 herringbone milking systems, 1958

Item	Double-4	Double-5	Double-6	Double-8	All
	Number	*Number*	*Number*	*Number*	*Number*
Total farms	12	5	24	6	47
Total cows timed	376	293	1,429	220	2,318
Cow routine time per cow:	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
Let in and feed	0.14	0.13	0.10	0.09	0.11
Prepare	.29	.31	.24	.27	.26
Move and attach machine	.18	.17	.14	.19	.16
Check, aid, and remove machine	.34	.39	.26	.39	.30
Let out	.11	.11	.09	.10	.10
Total routine time	1.06	1.11	.83	1.04	.93
Machine-cycle time per cow:					
Machine on	6.28	6.47	5.87	5.96	6.02
Idle machine	.99	.79	.80	1.13	.86
Total cycle time	7.27	7.26	6.67	7.09	6.88
Measures of efficiency:					
Cows per man-hour (number)	33	41	54	34	---
Pounds milk per cow per milking	16.6	18.4	17.2	16.9	17.2
Man-minutes per pound of milk	.11	.08	.06	.10	---
Machine-minutes per pound of milk	.45	.39	.39	.42	---

Cleanup Times

At the conclusion of the milking operation, the watches on the time board were allowed to continue through the cleanup operation. Some operational overlap was found between the milking process for the last half-cycle of cows in the parlor and the first phases of the cleanup operation. While milking was finishing on the side of the parlor that was last to milk out, the operator usually brushed out the opposite side and began to clean the floor and walls with the hose. By the time the last cow was out of the parlor, one side of the parlor had often been cleaned. The average times for the cleanup operations are presented in table 4 according to the size of the herringbone. Certain operations were affected by the size of the system. Other work elements were affected by the working pace and routine of the operator and the layout and design of the system.

Table 4.--Analysis of cleanup times for 47 herringbone milking parlors, 1958

Item	Double-4	Double-5	Double-6	Double-8
	Number	*Number*	*Number*	*Number*
Total farms	12	5	24	6
Total cows timed	376	293	1,429	220
Time per milking to--	*Minutes*	*Minutes*	*Minutes*	*Minutes*
Hose down milk units and milklines	1.14	1.26	1.41	1.77
Unhook milk units	.73	.92	1.08	1.39
Carry units to milk room	.92	1.06	1.10	1.74
Unhook lines	.26	.21	.29	.24
Disassemble units and fix rinse water	1.06	1.18	1.33	2.09
Hook up milk units to wash manifold	.21	.24	.27	.32
Rinse system	2.61	3.87	2.98	2.73
Drain rinse water	.41	.29	.62	.79
Fix wash water	.88	1.02	1.33	1.86
Wash cycle	14.13	15.09	17.69	21.42
Brush out parlor[1]	[2.47]	[3.16]	[4.12]	[5.74]
Hose down and scrub parlor[1]	[7.26]	[9.11]	[12.12]	[13.59]
Wash milk room[1]	[.93]	[1.22]	[1.16]	[2.09]
Total	22.35	25.14	28.10	34.35

[1] Figures enclosed in brackets are for elements performed while wash cycle is in progress.

TRAVEL ANALYSIS

Operator travel in the herringbone milking parlor and in the conventional two-sided tandem walk-through parlor differ only in the linear distance traveled between cows on each side of the pit area. Linear travel between cows in the herringbone is approximately one-third that in the conventional parlor, but not all travel in the herringbone is limited to the linear movement of the operator. Data on the distance traveled by the operator in performing the milking operation are presented in table 5 for herringbones of different sizes.

Table 5.--Operator travel during the milking operation for 6 herringbone milking systems, 1958[1]

Item	Double-6	Double-6	Double-6	Double-6	Double-8	Double-8
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Cows milked	60	50	72	44	48	59
Operators	1	1	2	2	2	2
Cows milked per man-hour	57	69	28	27	34	35
Travel per cow per milking:	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Admit and feed	5.83	5.95	2.94	3.14	6.67	13.51
Prepare cow	8.18	7.73	4.90	5.16	10.56	10.41
Move and attach machine[2]	5.00	5.00	5.00	5.00	5.00	5.00
Check, aid and remove machine	5.07	10.32	8.17	8.18	6.58	11.49
Let out cow	3.18	1.31	7.44	3.84	2.96	8.49
Total	27.26	30.31	28.45	25.32	31.77	48.90

[1] The data from which this table was assembled were collected by Thayer Cleaver and J. W. Rockey, Agricultural Engineering Research Division, Agricultural Research Service, and M. M. Lindsey, Farm Economics Research Division, Agricultural Research Service. The evaluation and the tabulation were made by Thayer Cleaver, who is stationed at Davis, Calif.

[2] The move and attach machine travel and the check, aid and remove machine travel were combined data originally, but a value of 5 feet, the typical pit width, has been assigned to the move and attach machine travel, thus leaving the residual figure as check, aid and remove machine travel.

The differences in travel distance between the herringbone systems shown in table 5 are due to the layout of the systems and the inability of certain equipment to function properly. This was particularly true of the last double-8 system presented, where a malfunction of an electrical switch kept one operator scurrying back and forth to make sure the motor stopped after each feeding sequence. This caused the "admit and feed" travel for this system, 13.51 feet per cow, to be considerably greater than that for the other systems. If these systems were normalized and the unnecessary delays and variables removed from the operational sequence, the operator travel distance per cow for each milking operation would probably range from 25 to 30 feet.

Table 6 presents a travel analysis of the entire milking sequence for the 6 herringbone systems shown in table 5. The differences in travel in the overall travel sequences are again due partly to system layout and poorly functioning equipment. If the figures for the operational sequences were normalized, the distance traveled per cow per milking would probably range from 35 to 45 feet. This would mean that the daily travel per cow, assuming 2 milkings per day, would range from 70 to 90 feet for the entire milking procedure. In 1952, George Byers[4] at the University of Kentucky made a "suggested method" analysis of chore travel for the double-2 tandem walk-through milking parlor. When the noncomparable data are omitted from Byers' analysis, the daily operator travel distance per cow for the entire milking sequences amounted to 111.9 feet. Estimated operator travel per cow in a properly functioning herringbone system should not exceed 75 feet per day.

[4] Byers, G. B. Effect of Work Methods and Building Designs on Building Costs and Labor Efficiency for Dairy Chores. Ky. Agr. Expt. Sta. Bul. 589, 55 pp., illus., 1952.

Table 6.--Operator travel for the entire milking sequence for 6 herringbone milking systems, 1958[1]

Item	Unit	Double-6	Double-6	Double-6	Double-6	Double-8	Double-8
Cows milked----------------	Number	60	50	72	44	48	59
Operators------------------	do.	1	1	2	2	2	2
Cows milked per man-hour----	do.	57	69	28	27	34	35
Travel per cow per milking:							
System preparation--------	Foot	14.72	11.68	5.15	9.59	18.02	15.34
Milking operation---------	do.	27.26	30.31	28.45	25.32	31.77	48.90
System cleanup------------	do.	2.70	2.83	4.32	2.77	4.13	.71
Miscellaneous and delay---	do.	.04	0	2.44	.14	1.77	1.92
Total-------------------	do.	44.72	44.82	40.36	37.82	55.69	66.87
Daily travel per cow------	do.	89.44	89.64	80.72	75.64	111.38	133.74
Yearly travel per cow-----	Mile	6.18	6.20	5.58	5.23	7.70	9.24

[1] The data from which this table was assembled were collected by Thayer Cleaver and J. W. Rockey, Agricultural Engineering Research Division, Agricultural Research Service, and M. M. Lindsey, Farm Economics Research Division, Agricultural Research Service. The evaluation and the tabulation were made by Thayer Cleaver, who is stationed at Davis, Calif.

PERFORMANCE STANDARDS

Standardizing performance times for work elements is not easy. The average times actually used for different work elements in the herringbone systems were presented in table 3. These averages, however, contain not only the performance time but also idle time, delay time, malfunction-of-equipment time, and time lost in other ways. As a time standard is basically the time required under specified conditions to perform a function or job element, these averages cannot apply as standards. In developing a standard time for work performance, it is necessary to analyze the original data and to select those performance times from which all nonessential time is removed. These selected standards, however, should not reflect superior work performance; they must be obtained easily through the work capacity of the average operator. The time standards that resulted from study of the original data are presented in table 7.

The work elements are divided into two groups--the work elements whose performance times depend upon the size of the herringbone system and those elements that are independent of system size and depend instead upon the working pace of the operator. The herringbone systems are grouped into one- and two-man systems because travel time is reduced in two-man systems if there is no duplication of work routes. In the two-man system, one man usually handles the entrance doors and feeds; the other opens and closes the exit doors. The double-6 herringbone is included in both groups, and the difference in total time is due to the amount of travel time saved when two operators are present in the system.

MILKING CAPACITY

The theoretical capacity of the herringbone milking systems can be determined by using the performance standards shown in table 7. By grouping the work elements in their proper sequence and totaling the time standards allowed for each element, an overall routine time for cows can be developed for a half-cycle in the parlor. Then the number of half-cycles per hour can be multiplied by the number of milking

Table 7.--Standard number of man-minutes per cow required for milking in two-sided herringbone milking systems, 1958

Work elements	One-man systems			Two-man systems	
	Double-4	Double-5	Double-6	Double-6	Double-8
	Minutes	*Minutes*	*Minutes*	*Minutes*	*Minutes*
Elements dependent on size of herringbone:					
Let cows in	0.12	0.11	0.10	0.08	0.08
Let cows out	.12	.10	.09	.08	.07
Elements controlled by operator pace:					
Prepare cow[1]	.21	.21	.21	.21	.21
Prepare cow[2]	.38	.38	.38	.38	.38
Move and attach machine	.15	.15	.15	.15	.15
Check, aid and remove machine[3]	.19	.19	.19	.19	.19
Check, aid and remove machine[4]	.34	.34	.34	.34	.34
All work elements:					
Short-preparation, short-stripping routine	.79	.76	.74	.71	.70
Short-preparation, long-stripping routine	.94	.91	.89	.85	.85
Long-preparation, short-stripping routine	.96	.93	.91	.88	.87
Long-preparation, long-stripping routine	1.11	1.08	1.06	1.03	1.02
Normal routine	.95	.92	.90	.87	.86

[1] Cow entering parlor is free of dirt and mud on flanks and udder and requires little washing.
[2] Cow entering parlor has dirty or mud-caked flanks and udder requiring a thorough washing.
[3] Cow is allowed to milk out by machine action, and stripping consists of a brief udder massage while maintaining downward pressure on the milking cluster just before it is removed.
[4] Stripping is more pronounced; the udder is thoroughly massaged during the final milking stage.

units to determine the theoretical capacity of each system in cows per hour (table 8).

As previously mentioned, one of the major controversies surrounding the first herringbones in this country centered around selection of the optimum size herringbone for one-man operation. This point is still of concern to dairymen and to their advisors.

In the course of the study, single-operator herringbone systems ranging in size from a double-3 through a double-8 were observed during the milking operation. Considerable idle-operator time was noted during the milking sequence in the double-3; the operator had to wait for the three cows on one side to milk out after he had let in and prepared the three cows on the opposite side. In contrast, the operator of the double-8 herringbone had to work at a furious pace and seemed to be behind in his work schedule most of the time. In many instances, he removed milking units and hung them up because he did not have enough time to attach the machines to the cows on the opposite side of the parlor without allowing the remaining machines to stay on the cows too long. This meant that some machines were idle for several minutes before the operator could find time to come back and attach them to the next group of cows. As one of the major advantages of a properly managed herringbone parlor is the low percentage of idle-machine time, it was apparent that this

Table 8.--Theoretical milking capacity of two-sided herringbone systems[1]

Herringbone size	Milking units	Half-cycles per hour			Cows milked per hour		
		Minimum	Normal	Maximum	Minimum	Normal	Maximum
One-man systems:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Double-4	4	11	11	11	44	44	44
Double-5	5	11	11	11	55	55	55
Double-6	6	[2] 9.4	11	11	56	66	66
Two-man systems:							
Double-6	6	11	11	11	66	66	66
Double-8	8	11	11	11	88	88	88

[1] Based on standard times given in table 7 in which cow milk-out time is assumed to be 5.5 minutes.

[2] Cow is waiting on the man. In all other instances, man is waiting on the cow.

double-8 system was too large for its single operator.

The optimum sized parlor should be balanced so that the operator has sufficient time to perform the necessary work routine on one group of cows before the first machine is ready to be removed from the second group. This balance seldom occurs exactly; but, as some delay is usually present in the operation of any system, the time difference should favor the operator.

The decision on the optimum sized one-man herringbone system is based primarily on the ability or work capacity of the operator, who must perform an entire work routine on one group of cows in a period of time measured by the milking time of the second group. Operators, of course, make every effort to see that the milking machines are removed from the cows as soon as they have completed milking. The chief drawback is the fact that cows vary by as much as 5 or 6 minutes as to milk-out time. For instance, one cow may milk out in 4 minutes, while another may require 9 minutes. An operator might possibly take care of seven or eight cows in 9 minutes, but the machine would be on the first cow much too long. If, however, only 3 cows in 50 milk out in 4 minutes, it is not wise to base the herringbone size on a 4-minute work routine, as the operator would be obliged to wait for the rest of the herd to milk out.

In choosing a one-man herringbone system, the chief aim is to select a system that fits the work requirements and milk-out times of 70 to 75 percent of the herd. In this case, approximately 15 percent of the cows would have longer and 15 percent would have shorter milking times than the time allotted. The only loss of system efficiency for the 15 percent that require more milking time would be in the milking of fewer cows per man-hour. No harm to the cows would result, as the operator would be ready and waiting to remove the machine. The chief concern is with the 15 percent that would milk out in less than the allotted time. Possible harm could result from sustained overmilking if the milking unit were allowed to remain on the cow after milking was completed.

To correct this condition, the operator may need to remove the machine from the fast-milking cow immediately after he has completed the work on the next group of cows. This may involve a breakup of the logical operating sequence--the fast-milking cow may be the third cow in line rather than the first. The additional time required to remove the milking unit in a nonscheduled move must be added to the work-requirement time to determine whether the operators can still get back to the 70 percent of the cows that fall within the base-time allotment. This theory was first advanced by Russell E. Larson,[5] Agricultural Engineering Research Division, Agricultural Research Service, stationed at the University of Minnesota.

To develop this theory, some assumptions must be made. The cows are assumed to produce about 16 pounds per milking, or

[5] Larson, R. E. The Use of Standard Data to Determine the Optimum Size Herringbone Milking Parlor for a One-Man Operation. Paper presented at the annual meeting of the American Society of Agricultural Engineers, Ithaca, N. Y., June 1959. (Unpublished.)

10,000 pounds per year. The average milking time for these cows is $5\frac{1}{2}$ minutes, with a range of $3\frac{1}{2}$ to $9\frac{1}{2}$ minutes. About two-thirds of the cows will milk out in $4\frac{1}{2}$ to $6\frac{1}{2}$ minutes.[6] The remaining third will consist of a group that milks out in less than $4\frac{1}{2}$ minutes and a group requiring more than $6\frac{1}{2}$ minutes. The concern here is mainly for the group that milks out in less than $4\frac{1}{2}$ minutes--approximately 1 in 6 cows milked. If the milking herd is divided into groups of 6 cows each, as in the double-6 herringbone system, how often would more than 1 fast-milking cow occur in each group? The probability of occurrence was computed and found to be 0.26323. This indicates that in 1 of 4 groups of 6 cows, the operator can expect more than 1 fast-milking cow. When this happens, the other 3 groups will contain no fast-milking cows. For practical purposes, therefore, it is safe to assume that in most instances each group of 6 cows will contain only 1 fast-milking cow. In groups of 4 and 5 cows each, such as are encountered in the double-4 and double-5 herringbone systems, occurrence of fast-milking cows would be even less frequent.

If we assume that in most instances the milk-out time for only 1 cow in each group entering the herringbone is less than $4\frac{1}{2}$ minutes, a safety time factor can be computed that will allow the operator to remove the machine from this cow in a "nonscheduled" move and still be ready to remove the milking machine from the other cows in the $4\frac{1}{2}$- to $6\frac{1}{2}$-minute groups. How much time should be allotted for the out-of-routine move necessary to go to the fast-milking cow, remove the milking unit, and proceed to the next cow in the schedule? As the fast-milking cow may appear in any stall position in the parlor, the mid-stall position was chosen because this is the average distance traveled by the operator. The travel time required varies from 0.05 to 0.09 minute according to the size of herringbones, that is, the length of the operator pit. An average travel time of 0.07 minute and the short-stripping routine of 0.19 minute for removing the machine from the cow are assumed. When these times are combined, they yield an out-of-routine time of 0.26 minute. This means that the work-requirement time for the cows in each group, plus the 0.26 minute of out-of-routine time for a fast-milking cow, should not exceed $4\frac{1}{2}$ minutes (table 9).

Study of data in table 9 would suggest that the double-4 is the only size herringbone shown that can be operated satisfactorily by one man. The figures under the double-5 herringbone system indicate that, if 1 of the 3 cows present in one side of the parlor who are in the $4\frac{1}{2}$- to $6\frac{1}{2}$-minute milking range should happen to milk out in exactly $4\frac{1}{2}$ minutes, the machine would remain on this cow 0.41 minute too long. Assuming

Table 9.--Schedule of work-requirement time compared with milking-out time for one-man herringbone milking systems

Item	Double-4	Double-5	Double-6	Double-8
	Minutes	*Minutes*	*Minutes*	*Minutes*
Work-requirement time[1]	3.84	4.65	5.46	6.96
Time allotment for fast-milking cow[2]	.26	.26	.26	.26
Total time required	4.10	4.91	5.72	7.22
Milking-out time	4.50	4.50	4.50	4.50
Difference	.40	-.41	-1.22	-2.72

[1] The work-requirement time for the group of cows in the operation of each half-cycle of the parlor is computed by totaling the cow routine time for each cow.

[2] The time allotted for a nonscheduled move necessary to take care of a fast-milking cow is computed by adding the additional travel time to the removal time required to take the machine off the cow.

[6] If the standard deviation is considered to be approximately one-sixth of the range, it will be about 1 minute. A range of plus and minus one standard deviation from the average milk-out time of $5\frac{1}{2}$ minutes encompasses 68.27 percent of the cows.

that the two-thirds of the herd that milk out in the 2-minute interval between $4\frac{1}{2}$ and $6\frac{1}{2}$ minutes are fairly evenly spaced, only 1 in 14 cows in this group would milk out in the 4.50- to 4.91-minute interval. This infrequent occurrence, plus the opinion of many dairy specialists that the 0.41 minute would not constitute severe or injurious overmilking, may lead many farmers to select the double-5 as the optimum sized herringbone system for one-man operation.

Data in table 9 indicate that choice of the double-6 herringbone as a one-man system may be out of the question. The 1.22 minutes that the milking machine is allowed to remain on the first cow in the $4\frac{1}{2}$- to $6\frac{1}{2}$-minute group after milking is completed constitute overmilking and mean that each subsequent cow would have to wait approximately the same time before the machine is removed. Frequently, therefore, the operator would be behind in his work during most of the milking job. Despite his best working pace, he could never really catch up.

Perhaps an observation about the double-6 herringbone system is in order here. During the time study made for this analysis of the herringbone system, a number of single-operator double-6 herringbone milking systems were observed in which the milking performance was considered to be adequate. The average milk-out time for the herd was good and the cow routine times were excellent. The operators worked at a fast but unhurried pace (probably at or in excess of 125 percent of normal) and were in command of the system during the entire milking sequence. These men were good operators; in most cases, they owned the herds they milked and knew the individual cows and their characteristics. Although they moved fast, they were constantly planning the work routines ahead in view of the cows that were currently in the parlor. They did not hesitate to interrupt any work sequence in order to take care of a cow that was out of the ordinary.

For example, suppose an operator were to notice a fast-milking cow in position 4 on the left side of the parlor. Instead of going through the entire work sequence of washing all six cows on the right side of the parlor before removing any milking units from cows on the left side, he would move directly to the cow in fourth position on the right side, prepare her, and then immediately transfer the machine from left 4 to right 4. This would permit him to remove the machine from cow left 4 sooner than would be possible if he waited to wash, dry, and forestrip the six cows on the right side. When the one milking unit was transferred, if no other cows had completed milking, the operator would continue with the preparation of the remaining five cows on the right side. If another cow were to complete milking, however, he would move to the cow on the opposite side of the parlor, prepare her, and again make the milking-unit transfer described.

This type of work sequence requires more operator travel and therefore increases the work-requirement time per cow. But if we assume that one cow in the group will require more than $6\frac{1}{2}$ minutes of milking time, the operator can perform all work requirements in the time available. This discussion is based on an above-average operator with an intimate knowledge of the herd he milks.

Data in table 9 show that the double-8 herringbone is too large a system for proper one-man operation. Machines would remain on many cows 2 or 3 minutes after milking is completed.

ADJUSTMENT POSSIBILITIES OF THE HERRINGBONE MILKING SYSTEM

Before adopting the herringbone parlor as a new milking system, farmers should realize that the herringbone alone does not constitute a completely balanced unit of operation. The operation of any milking parlor at optimum efficiency, that is, with the maximum number of cows milked per man-hour, depends upon a completely balanced farmstead system, of which the parlor is only a part. Other components may include loose housing, pipeline milking with in-place cleaning, bulk milk tank, bulk feed handling with mechanical feeding, paved feedlots, and a good drainage system. The herringbone parlor can be operated without some of these components, but efficiency and perhaps net returns would be hampered by their absence.

In addition to the adjustments necessary for optimum efficiency in the herringbone milking system, a farmer may face many other management decisions in order to maximize his farm income. The management decisions may involve farm size, herd size, size of milking system, size of labor force, choice of feed-crop enterprises, and

choice of feedstuffs and feeding systems. The farmer can study the trends and effects that long-run operation of the herringbone system may create, and may change or modify his system accordingly. Some possible choices and alternatives open to dairy farmers who may wish to select a herringbone milking system are presented here.

The adjustments discussed in this section do not include all that might be made. Only the major items considered as indispensable to efficient operation of the herringbone system are included. As the operator becomes familiar with the system, he may become aware of other adjustments that would be desirable in the interest of overall efficiency of production.

LOOSE HOUSING

Loose housing is an important feature of any milking parlor operation because of the way in which the herd enters and leaves the parlor. In the herringbone and most other milking parlors, the cows are grouped in a holding area at the entrance end of the parlor. They enter the milking room at random, ordinarily without guidance by the operator. The operation of a herringbone parlor in connection with a stanchion barn requires more labor, as each cow must be released and retied in the barn at each milking. This combination is usually handled by two operators; one releases and ties the cows in the stanchions and the other carries on the milking operation. The loose-housing milking parlor arrangement can be handled by one operator alone, as the cows are free to move at will while outside the parlor.

Most farmers who contemplate the installation of a herringbone milking system are established dairymen; they have various farm structures in use as dairy service buildings. Many of these buildings are structurally sound and stable, but they may be functionally obsolescent because of changes in dairy production technology. A farmer who uses a method of depreciation in his tax accounting that is based on the structural life of a building may find that he has a half-depreciated building for which he no longer has any effective use. If the building is to be of use in the new system, it may require extensive modification, and the question is always present as to the efficiency and cost of operation of a remodeled structure as compared with a new one. Most farmers believe that they are not economically justified in scrapping a building that is structurally sound. Finding an economic use for such a building is one of the major problems that confront farmers who wish to install a new system such as the herringbone. The exact point at which functional obsolescence costs more than a new structure is difficult to determine. In addition, depreciation of the building is spread over a fairly long period, whereas a farmer is likely to think of the erection of a new building as an initial cost that must be borne in a lump sum, even though the use of the building will be spread over many years.

When a farmer adopts the herringbone milking system, a stanchion barn is often the focal point in making the switch from the old to the new system. Most stanchion barns are still serviceable from the standpoint of structural stability, but they do not lend themselves well to the loose-housing systems so necessary to efficient operation of herringbone parlors. It may be best to abandon the barn as part of the milking system and use it for some other purpose, such as storage for machinery, extra hay and bedding, grain, and so on. Some farmers have used stanchion barns to separate dry cows, heifers, and calves from the milking herd, as the barns usually have facilities for hay, grain, and silage.

If a farmer feels that his stanchion barn must be incorporated into his new herringbone system, the building can be utilized in several ways. The stalls, walkways, feed troughs, and gutters can be removed to create an open area under the haymow. By adding side sheds that are left open on one side, he can have a loose-housing area that will probably handle an expanded herd. The additional storage space needed for hay, grain, and silage should be at ground level. A feeding area can be provided on an outside paved lot located at the side of the shed that is left open.

If the farmer constructs a silage feed bunk down the center of the converted stanchion barn, with an overhead hayrack, he can mechanize the feeding of silage from his existing silos and can also feed hay efficiently. A slot 3 to 4 feet wide down the center of the haymow over the silage bunk will mean that he can keep the hayracks full by dumping the hay down through the slot. Enough space should be allowed at each end

of the feed bunk for the passage of a tractor for cleaning operations.

Most stanchion barns converted to loose-housing systems do not have sufficient storage for hay, silage, and bedding. Many farmers store straw for bedding in the overhead areas of sheds that flank the stanchion barn. A storage area of this kind is simple. It usually consists of a latticework of 2 by 4 timbers across 2 by 6 ceiling joists that help tie the shed to the stanchion barn. Bedding can be easily put in and removed. If additional silage is needed, a bunker silo may be constructed adjacent to the paved feedlot. The silage may be fed in a self-feeding arrangement or in feed bunks constructed on the paved feeding area. Some farmers like to feed inside the converted stanchion barn in bad weather and outside in good weather.

The expense of this type of conversion is a basic disadvantage. Removal of the partitions, stanchions, gutters, curbing, and so on from the building and construction of lean-to sheds will run the cost per square foot of usable space fairly close to the cost of constructing a pole-type loose-housing barn. An additional disadvantage is the overhead storage of hay. It is hard to get hay into and out of the haymow above the barn. The hay must be fed down through the openings in the mow. It cannot be self-fed, as it usually is when stored at ground level.

A third disadvantage is that more bedding is required in loose housing than in the stanchion barn. When the cows are fed inside the converted unit, the bedding becomes soiled by the milling of the herd during feeding, and sizable amounts of additional bedding material are required. The amount of bedding can be reduced if no feeding is done inside the loose-housing area and the cows eat and drink in the outside paved feeding area.

In the open area of the conventional pole-type, loose-housing barn, a tractor with a blade can make short work of the cleaning operation. But the converted stanchion barn-loose housing unit usually has a low ceiling and columns to support the haymow. These two features complicate the cleaning routine, and considerably more time is needed to clean the converted stanchion barn because of the cramped space.

BULK FEED HANDLING

Handling all feedstuffs in bulk and feeding mechanically reduce substantially the amount of labor required for feeding. Most buildings that are built to house the herringbone system have large overhead grain bins adjacent to the parlor area. These bins hold several tons of feed that can be moved to the parlor through gravity chutes, augers, or other conveyors. Each chute or conveyor is equipped with a metering device that allows the operator to feed according to the need of each animal. The bins are filled by "filler pipes" or other conveying equipment which carry the feed pneumatically or mechanically from the carrier up to the bins.

Storage of hay and silage at ground level lessens materially the labor of getting feed into and out of storage and often permits self-feeding. It is practical to self-feed silage from bunker silos, and several types of hay storage allow self-feeding of hay.

If the farm has upright silos, they can be mechanized by installing a silage unloader coupled to a shuttle or auger-type bunk feeder. Most feeding systems that lend themselves to loose housing will give greater service if an outside paved feeding area is available.

FARM SIZE

Dairy farms are becoming fewer in number but larger in size--larger in both acreage and size of herd. But acreage is not the limiting factor in production that it has been in the past. Increased production per acre, crop specialization, and substitution of capital for labor have allowed expansion of the farm business without corresponding increase in the acreage of the farm.

The purchaser of a herringbone system often wants to enlarge his dairy enterprise. But he may not be able to increase either acreage or crop yields per acre enough to produce the grain, hay, silage, and pasture needed for an expanded milking herd. In

such cases some farmers may find it best to shift from production of grain for feed to the production of forage crops, and to buy grain. By utilizing all available land for green-chop feed, silage, and hay, they can carry the maximum number of cows per acre. If land is very limited, they may try complete drylot operations.

CASE STUDIES

Three farms were chosen to show the impact of the herringbone system on farms of varying sizes with differing possibilities for expansion.

Farm No. 1

Farm No. 1 is a midwestern farm owned by a 26-year-old man who has been in dairying for only a few years. The farm has 206 acres, about 200 of which are in cultivation. In the past, the operator depended upon mixed livestock, dairying, and cash grain crops for his income but came to believe that this diversification required too heavy an investment in equipment. He decided to produce only feed crops and eventually to work out of the mixed livestock enterprises, but to expand the dairy enterprise from 12 to about 40 cows over a 2- to 3-year period.

In order to expand, he had to remodel his existing dairy facilities. The old stanchion barn had 20 stalls, in which two milking units were used to milk 12 cows. Each milking required an hour.

The farmer built a new double-4 herringbone milking system to fit the needs of his expanding dairy enterprise. With his own labor, he put up a concrete building, which included the milking parlor and milk room, at a cost of $2,400. Other new buildings included a 36- by 75-foot creosoted pole-type loafing barn with galvanized sheeting on the roof and on three sides, and a 26- by 30-foot pole-type hay barn of the same construction. He concreted a 56- by 75-foot feeding area in front of the loafing barn that extended around the hay structure to the herringbone milking parlor. These buildings and special features cost $5,600.

The milking equipment included stalls and feeders at a cost of $900, pipeline and in-place wash system at $2,200, and a 300-gallon bulk tank at $2,600, or a total cost of $5,700. The sale of old equipment reduced this by $540, leaving a net cost of $5,160 for milking equipment.

The total investment in the new herringbone milking system, together with the related barns and facilities, amounted to $13,160. This may seem high, but the operator has been in dairying for only 2 years and, before adopting the herringbone, had virtually no facilities that would permit good dairying. The new facilities will handle 40 cows easily, as compared with 12 cows in the stanchion barn, and with no increase in labor requirements (table 10).

Table 10.--Farm No. 1: Summary of milking operation before and after installation of herringbone system.

Item	Unit	Before	After
Cows milked	Number	12	40
Milking units	do.	2	4
Men working	do.	1	1
Time per milking:			
Milking	Crew-minute	60	70
Milking	Man-minute	60	70
Preparation and cleanup	do.	45	30
Total	do.	105	100
Cows milked per man-hour	Number	12	34
Time per cow per milking including preparation and cleanup time	Man-minute	8.8	2.5

The operator of this farm believes that he will be better off financially with the new system, his larger dairy enterprise, and his more specialized farm. With increased efficiency in the dairy setup, and assuming no major change in price relationships, his net income from the dairy herd should more than offset the reduced income from other livestock and from cash grain crops.

Farm No. 2

Farm No. 2 is in the Northeast; it had been in operation as a dairy farm for many years before a herringbone milking system was installed in 1958. Existing facilities were outmoded, and the stanchion barn was much too small for the milking herd. The 38-year-old operator decided to install a double-6 herringbone system, build loose-housing facilities, remodel other service buildings if necessary, and finally, expand his herd.

The old barn had 48 stanchions; the operator milked 76 cows in two shifts. The second shift of cows was housed in an old stable when housing was required. The operator and one helper did the milking, using 4 milking units. Each man operated 2 milking units and carried the milk to the milk room, an average distance of 80 feet. The actual milking took 2 hours, but an additional 15 minutes was needed to let out the first shift of cows and turn in the second. If we use the actual milking time of 2 hours, milking was done at the rate of 19 cows per man-hour; but if we use the 2-1/4 hours of total elapsed time, milking was done at the rate of 17 cows per man-hour.

The time required for preparation--setting up the milking units, moving from the milk room to the barn, and arranging the equipment--amounted to 25 man-minutes per milking. Cleaning and bedding the stanchion barn and stable barn required 1-1/2 man-hours per day, or 45 man-minutes per milking. Grain was fed during the milking operation; but, when hay and silage were fed, an additional 30 man-minutes per milking was required for this operation.

The change from the old system to the herringbone milking system was a well-planned move, and the operator was definite as to the new facilities he wanted and needed. The herringbone building was constructed of concrete blocks, and the interior was faced with tile brick from floor to ceiling. The concrete floor in the parlor was treated with a special finishing material to help make the surface resistant to the action of milk acids and manure. Overhead grain bins were constructed the length of the milking parlor. Rest and change rooms were provided. All entrances and exit lanes and roads were paved at the time the building was erected. This structure and its related facilities, which include site grading, plumbing, wiring, and concrete work, cost $6,600. The stalls, feeders, pipeline milking units, compressor, wash system, hot water heater, and so on, cost about $4,400. A 400-gallon bulk tank added $3,050 to make the total cost of this part of the system $14,050.

In addition to these costs, the operator built a 120- by 39-foot loafing barn with a 120- by 50-foot concrete apron for $2,900. A 60- by 22-foot concrete stave silo with automatic unloader and feed bunk with feeding auger was erected on the concrete apron at a cost of $4,900. The old stanchion barn was remodeled for hay storage and for a feeding area when, because of inclement weather, the cows could not be fed on the paved feeding apron.

The new facilities cost approximately $22,000 but permit a much larger herd to be handled with less labor. Although the milking herd has now increased to 132 cows, the operator does all the milking himself (table 11). Man-minutes of labor required per cow have been reduced by 3 minutes per milking. The entire herd is bedded in one area, and the herd is no longer shifted during milking. Increased milking efficiency has made possible the addition of 56 cows to the herd.

Farm No. 3

Farm No. 3 was included in this series of case studies to illustrate the larger dairy enterprises that will become more numerous in the future. Not many farmers now have milking herds of 100 cows or more, but the trend is in this direction. In some instances, particularly in areas with small dairy herds on general farms, farmers are pooling their herds so the costs of a new milking system can be spread over more

Table 11.--Farm No. 2: Summary of milking operation before and after installation of herringbone system

Item	Unit	Before	After
Cows milked	Number	76	132
Milking units	do.	4	6
Men working	do.	2	1
Time per milking:			
Milking	Crew-minute	135	160
Milking	Man-minute	270	160
Preparation and cleanup	do.	70	35
Total	do.	340	195
Cows milked per man-hour	Number	17	49
Time per cow per milking including preparation and cleanup time	Man-minute	4.5	1.5

animal units. In other instances, farmers are building milking parlors large enough to handle additional cows or of a design that will permit more milking stalls to be added as the herd expands.

Farm No. 3 is a long-established dairy farm in the southeast region. Before the herringbone milking system was installed, the cows were milked in a 56-stall stanchion barn over 40 years old. The 100-cow milking herd required a shift of cows during each milking period. Under the stanchion barn setup, two men handling three milking units each spent 2 hours and 45 minutes at each milking. Preparation and cleanup time amounted to 1 hour and 10 minutes per milking. Hay and silage were fed in bunkers, and this practice was continued after the shift to the herringbone system.

The decision to install the herringbone milking system resulted from an increase in herd size to the point at which two shifts of cows were necessary during each milking operation. In addition, it had become increasingly difficult to get good labor under these conditions. As the farm includes about 2,000 acres, an expansion in the herd seemed both feasible and desirable to permit economic use of resources.

A double-10 herringbone milking parlor was installed in a new building constructed for the purpose. Construction featured a concrete block exterior with the interior faced with glazed tile. With overhead grain storage, milk room, storage room, and office, the building cost $5,400. The stalls, feeders, milking units, pipeline milking system, pump, hot water heater, 700-gallon bulk tank, and semiautomatic wash system cost about $11,000. Additional barn space was provided by constructing a pole-type loafing barn 160 feet by 40 feet with a covered walk to the milking parlor. This unit cost $4,500. The total investment in the new facilities amounted to about $21,000. The operator already had a huge trench silo with a powered auger-type loader and a self-unloading wagon for feeding in outside feed bunkers.

In the herringbone milking parlor, two men operate five milking units each. The 200-cow milking herd is milked by the two men in about 2 hours and 45 minutes, the same amount of time required to milk 100 cows in the stanchion barn. Preparation and cleanup time amounted to about 40 man-minutes per milking (table 12).

The owner has doubled the milking herd since he shifted to the herringbone system, and he will add more cows later. He believes that the present milking system will easily handle 500 cows, but he plans to level off at about 250. He has found it easier to keep labor since installing the system, and mastitis has been reduced. He plans to concrete a large paved feeding yard adjacent to the loose-housing barn before another winter to eliminate the muddy areas that develop around the feed bunk and watering facilities.

Table 12.--Farm No. 3: Summary of milking operation before and after installation of herringbone system

Item	Unit	Before	After
Cows milked	Number	100	200
Milking units	do.	6	10
Men working	do.	2	2
Time per milking:			
Milking	Crew-minute	165	165
Milking	Man-minute	330	330
Preparation and cleanup	do.	70	40
Total	do.	400	370
Cows milked per man-hour	Number	18	35
Time per cow per milking including preparation and cleanup time	Man-minute	4.0	1.8

FUTURE TRENDS IN DAIRYING AS RELATED TO THE HERRINGBONE MILKING SYSTEM

When the 1954 Census of Agriculture was taken, the United States had approximately 850,000 farms from which milk was sold. The number is now much smaller. The trend has been toward fewer but larger herds. Seventy-three percent of the farmers who sold milk in 1954 had milking herds of fewer than 30 cows but produced less than 40 percent of the milk sold. The remaining 27 percent of the farmers had herds of 30 or more cows, and this group produced 60 percent of the milk sold. Not many farmers would need to be added to the group milking 30 or more cows to produce the amount of milk supplied by the 73 percent of the dairy farmers who had herds of fewer than 30 cows.

Each herringbone owner interviewed in the study was asked, "How many cows do you expect to milk in your system?" Forty-nine of the 51 farmers interviewed indicated that they expected to add to their herds. Thirty-six farmers said they intended to double their present herds in less than 3 years by keeping the heifers produced during this period. The remaining 13 farmers planned to add to their herds but thought that it would be a number of years before they could double them.

The chief reason given by herringbone owners for buying the system was to facilitate herd expansion. Most herringbone purchasers felt that they had to increase operations or get out of dairying. This reflected the rather general feeling among dairy farmers that they must have larger herds to justify the purchase of the equipment now so necessary for efficient dairying. Second in importance among reasons advanced for purchase of a herringbone system was "labor ease." By labor ease is meant the lessening of physical labor and strain, not a reduction in time spent on dairy chores. Farmers are becoming more conscious of strain on back and leg muscles and are trying to reduce its causes.

Most farmers who intend to add to their herds feel that the increase must be handled with the same, or even less, labor. Many of these dairymen utilize one-man dairy systems to handle their small milking herds. On farms of this type labor is usually a limiting factor, and herd size is determined by the number of cows one man can milk and care for. In recent years, the substitution of capital in the form of equipment and mechanized systems for labor has done much to change this traditional concept of the one-man dairy farm.

Pipeline milking systems, bulk tanks, bulk feed handling, mechanical feeding systems, barn cleaners, and other improvements have been responsible for a major reduction in time spent in performing dairy chores. The man-hours saved by new equipment and technology have been utilized to milk and care for more cows.

How many cows can one man expect to milk and care for on a modern, well-planned dairy farm, and what are the initial investment costs and operating capacity for such a system? Five milking systems were chosen for a comparison of one-man dairy farms: (1) The stanchion barn; (2) the loose-housing barn with a 3-stall in-line, side-opening milking parlor; (3) the loose-housing barn with a double-3, tandem, walk-through milking parlor; (4) the loose-housing barn with a double-4 herringbone milking parlor; and (5) the loose-housing barn with a double-5 herringbone milking parlor. The size or cow capacity of each system is based on the number of cows that one operator can milk in a continuous 2-hour period. The number of cows milked per man-hour will depend on the number of milking machines operated; the average milk-out time per cow (affected by cow's production level); and the time required to move cows into and out of the barn or parlor, feed and wash the cows, and attach and remove the milking unit. In this comparison, we assume that each cow produces about 8,500 pounds of milk per year and requires an average of 5.5 minutes to milk out.

Table 13 presents a comparison of size, cow capacity, investment costs, and milking efficiency for these five milking systems. The stanchion barn discussed here is a

Table 13.--Comparison of size, investment costs, and milking efficiency of five milking systems for a one-man dairy farm, 1958

Item	Unit	Stanchion barn system	Loose-housing barn with milking parlor			
			3 In-line side-opening parlor	Double-3 tandem walk-through parlor	Double-4 herring-bone parlor	Double-5 herring-bone parlor
Building dimensions:						
Stanchion or loose-housing barn----------------------	Foot	32x117	40x91	40x104	40x140	40x165
Milking parlor--------------	do.	none	11x31.5	10.5x31	16x21	16x24
Milk room------------------	do.	14x16	14x16	14x16	14x16	16x16
System design and features:						
Milking units---------------	Number	3	3	3	4	5
Stalls----------------------	do.	60	3	6	8	10
Bulk tank capacity----------	Gallon	500	500	500	600	750
Cow capacity----------------	Number	60	56	64	86	105
Investment costs, 1958 prices:						
Building costs--------------	Dollar	15,000	7,231	7,926	9,898	11,128
Per stall-----------------	do.	250	2,410	1,321	1,237	1,113
Per cow milked at capacity	do.	250	129	124	115	106
Equipment costs-------------	do.	7,800	4,809	5,350	5,900	6,873
Per stall-----------------	do.	130	1,603	892	738	687
Per cow milked at capacity	do.	130	86	84	69	65
Total system costs----------	do.	22,800	12,040	13,276	15,798	18,001
Per stall-----------------	do.	380	4,013	2,213	1,975	1,800
Per cow milked at capacity	do.	380	215	207	184	171
Milking efficiency:						
Cows per man-hour-----------	Number	30	28	32	43	53
Man-minutes per cow---------	Minute	2.00	2.14	1.88	1.40	1.13
Machine-on time per cow-----	do.	5.50	5.50	5.50	5.50	5.50
Machine-off time per cow----	do	.32	.89	.14	.14	.14
Idle-machine time-----------	Percent	5.5	13.9	2.5	2.5	2.5

modern two-story concrete block structure with a composition, metal, or crushed stone roof over wood decking. The foundation, footings, and floor are of poured concrete with preformed gutters and feed troughs. The windows have steel casements. Grain is stored at ground level, and hay is stored overhead. The barn is equipped with an "around the barn" milk pipeline, bulk tank, semiautomatic pipeline wash system, barn cleaner, ventilating system, and three milking units. Based on the number of cows one man can milk in a 2-hour period, the total cost of buildings and equipment is $380 per cow milked for this system. The 30 cows per man-hour is a maximum figure based on 5.5 minutes of milking time per cow and only 0.32 minute of idle-machine time per cow. These conditions are seldom met under actual milking conditions, and the average number of cows per man-hour in a typical stanchion barn will range from 18 to 22.

The loose-housing barns for the other three systems discussed are identical except for differences in size that arise from the differences in the number of cows that can be handled by one man in a 2-hour milking period. The barns are built of creosoted pole framing. Galvanized sheet metal is used for the roof and three sides; one of the long sides is left open. The barns have no floors. Heavy wooden walls treated with a good preservative extend from ground level up 3 to 4 feet on the inside of the pole-barn walls. These "bump or rub" rails prevent cows and cleaning equipment from bending and tearing the sheet metal walls. Bedding is stored at ground level, and hay and silage are fed in an outside paved feeding lot.

The milking parlors are built of concrete block faced with glazed tile on the interior walls, with poured concrete foundations and floors. Roofs are of composition, metal, or crushed stone and allow room for overhead grain storage. The equipment includes stalls, gravity type feeders, pipeline milking systems equipped with a semiautomatic wash system, bulk tank, hot water heater, doors, lighting fixtures, plumbing, and electrical wiring.

In the second system presented in table 13, a loose-housing barn is coupled with a 3-stall in-line, side-opening milking parlor equipped with three milking units. The chief drawback of this system is the relatively high percentage of idle-machine time while one cow is being let out and another brought in, fed, and washed. This idle time reduces the number of cows that can be milked per man-hour. The cost of buildings and equipment in this system is $215 per cow milked at system capacity. The theoretical capacity of the system is shown as 28 cows per man-hour, but under actual conditions the capacity usually will range from 22 to 26 cows per man-hour.

Rated by cost and efficiency standards, the double-3, tandem, walk-through milking parlor is considered to be one of the best conventional milking systems. The cows enter the parlor in groups of three and stand parallel to the operator's pit. Milking units are placed on the three cows on one side of the parlor, while the three on the opposite side are prepared for milking. As the cows milk out, the machines are shifted from the cows on one side to the waiting cows on the other side of the parlor. Idle-machine time and total operator time per cow are relatively low because cows are handled in groups of three and not as individuals. The building and equipment cost per cow milked for this system is $207. This system is rated at 32 cows per man-hour under assumed conditions, but the average double-3, tandem, walk-through milking parlor will usually deliver from 24 to 30 cows per man-hour.

The last two milking parlors shown in table 13 are herringbone milking systems. The efficiency of these systems results from group handling of the cows and placement of the cows in the parlor. The group-handling feature reduces the cow routine time and allows one group of cows to be readied for milking while the preceding group is being milked. The angle-parking feature of this arrangement permits a compact system in which the cows' udders are easily accessible to the operator and are spaced only 36 to 39 inches apart. The distance between the udders of the first and fourth cows on one side of the herringbone is about 9 to 10 feet as compared with 17 to 18 feet between the udders of the first and third cows in the 3-stall in-line and the double-3, tandem, walk-through parlors. Time spent in walking from one cow to the next is substantially reduced in the herringbone system. The compactness of the system reduces the area required per cow, thereby lowering building costs per cow. The building and equipment costs are only $184 per cow milked in the double-4 herringbone and only $171 per cow milked in the double-5 herringbone.

The double-4 herringbone system probably offers the best possibilities for the

dairy farmer who wishes to milk 35 to 40 cows and does not expect to milk more than 75 cows at any time. The double-4 herringbone requires less travel than either the 3-stall in-line or the double-3, tandem, walk-through parlor. This system can be easily operated by the older farmer who finds that he is not so fast as he was a few years ago. Table 13 shows that this system has a capacity of 43 cows per man-hour under perfect conditions, but the average operator will milk from 32 to 36 cows per man-hour under the actual conditions experienced in day-to-day dairying.

The double-5 herringbone is a possibility for young dairymen who need to continue to expand their milking herds over a considerable period of time. In this system as few as 40 cows can be milked efficiently, and if it is in operation 7 to 8 hours a day 135 to 150 cows could be handled. Coupled with an efficient loose-housing arrangement and good materials-handling equipment, it is probably the most flexible and the most efficient system now available for handling dairy cows. It has capacity for as many as 53 cows per man-hour. Under normal conditions it will handle from 40 to 45 cows per man-hour.

The change from a one-man dairy system, which in the past typically has included only 12 to 15 cows, to one capable of handling 75 to 80 cows constitutes a major reorganization. In many instances, the farmer has a stanchion barn that he feels he must continue to use. One of the greatest problems in reorganizing centers around the efficient use in the new arrangement of existing farm service buildings. However, careful planning will usually permit expansion of the dairy enterprise to a point at which the benefits of increased size and economy of scale can be realized. Continued increase in the number of such one-man systems for milking cows may soon require a revised definition for the "small" dairy farm.

If the trend toward larger milking herds is accelerated by such technological advances as the herringbone milking parlor, it is conceivable that in a few years less than 200,000 dairy farmers may be able to supply the milk needed in this country.

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